RP Note 151

Determining the Activity of EML Mixed Contamination Samples Using the LB5100 and XLB Sample Counters

F. Krueger
6/22/05

Prepared by	Fred Krueger Author	Date	8-18-05
Reviewed by:	Kamran Vaziri	Date	8/18/'05
Approved by:	Don Cossairt Associate Head, Radiation Physics Group	Date	8/23/05
Approved by:	William J. Griffing Head, ES&H Section	Date	8/24/2005

Electronic distribution

RP Note 151

Determining the Activity of EML Mixed Contamination Samples using the LB5100 and XLB Sample Counters

F. Krueger
8/18/05

1.0 Introduction

The Environmental Monitoring Laboratory (EML) periodically sends radioactive test samples to Fermilab for comparison analysis. These samples are a mixture of ^{230}Th and ^{90}Sr^{90}Y deposited on a closed cell polyfoam disk and placed in an aluminum planchet for counting. An analysis is possible using the calibration of the LB5100 and XLB wipe counting systems[1] for the specific isotopes. Allowances must also be made for the configuration differences between the EML samples and the Fermilab calibration standards. The Fermilab calibration standards vary, from the EML samples, in deposition surface, source cover, and backing material. The resultant differences in self-absorption and backscatter must be adjusted to provide counting system sensitivity equivalent to an open source deposited on closed cell polyfoam with an aluminum backing (reflecting the EML sample configuration).

EML sample equivalent calibration sensitivities must be determined for ^{230}Th and ^{90}Sr^{90}Y as well as a β/α count ratio for ^{230}Th. This allows mathematical extraction of both isotope activities from the EML samples.

2.0 Determining the effects of beta backscatter for the calibration sources and EML samples

Surface backscatter of beta particles can provide significant contribution to the overall counting rate. This varies with particle energy and backing material density. The Fermilab calibration standards used in wipe counting analysis are mounted or deposited on several types of metallic surfaces: stainless steel (SS); nickel (Ni); and aluminum (Al). The EML samples are placed in an aluminum planchet. Source calibration sensitivities, for the isotopes of interest, must be adjusted for backscatter from an aluminum surface to correspond to the EML samples. Referencing Tabata[2], β-backscatter estimates from the various surfaces can be performed. Tabata provides coefficients for Al, Fe and Cu, but not for Ni and SS. SS is essentially Fe. Ni can be estimated from the Fe and Cu values as they adjoin Ni in atomic number. Referencing Table 1:

> ^{90}Sr in equilibrium has two sources of emission, ^{90}Sr and ^{90}Y. Therefore:
> ^{90}Sr β-scattering off Fe, yields a calculated backscatter of 23.8%; and
> ^{90}Y β-scattering off Fe, yields a calculated backscatter of 16.7%.
> This results in an average of 20.3% as an estimate for total scatter from Fe backing.
>
> ^{90}Sr β-scattering off Cu, yields a calculated backscatter of 26.1%; and

^{90}Y β-scattering off Cu, yields a calculated backscatter of 19.0%.
This results in an average of 22.6% as an estimate for total scatter from Cu backing.

As the atomic number of Ni is between Fe and Cu and the backscatter is somewhat directly proportional to the atomic number, an estimate of scatter from Ni is obtained by adjusting the backscatter value by the fractional difference in atomic number. This results in an overall estimated backscatter estimate from Ni of 21.8%.

The EML samples are counted in Fermilab supplied aluminum planchets. Referencing Tabata, an estimate of the backscatter for ^{90}Sr and ^{90}Y from aluminum can be performed. Referencing Table 1:

^{90}Sr scattering off Al, yields a calculated backscatter of 11.0%; and
^{90}Y scattering off Al, yields a calculated backscatter of 6.1%.
This results in an average of 8.6% as an estimate for total scatter from Al.

The β component of ^{230}Th is a spectrum of particles primarily from ^{226}Ra daughters. Therefore, the backscatter component is determined by analyzing the effect of the β particles from each daughter isotope. ^{230}Th emits β particles of 8 dominant energies from ^{214}Pb, ^{214}Bi, ^{214}Po and ^{210}Bi. Referencing Tabata, backscatter estimates were performed for ^{230}Th β particles from Al, Cu and Fe, with the value for Ni acquired by interpolating between Cu and Fe values. The branching ratios for the indicated isotopes were used to obtain the effective backscatter component. From Table 1:

The average calculated backscatter for the ^{230}Th β spectrum scattering off Al, is 4.2%; the average calculated backscatter for the ^{230}Th β spectrum scattering off Fe, is 9.8%; and the average calculated backscatter for the ^{230}Th β spectrum scattering off Cu, is 10.9%. Interpolating for Ni results in an overall estimated backscatter of 10.6% for the ^{230}Th β spectrum.

Backscatter estimates from the EML sample aluminum planchets should include the absorption of the foam disk medium. Backscattered particles must pass through the foam medium twice before entering the sample counter detector. An estimate of the attenuation effect of the foam medium was performed by first counting each calibration source in its normal configuration[3,4,5], then with blank EML foam disks over each source[6 - 15]. The resulting attenuation effects as well as the effect on the backscatter from the EML samples is included in Table 2.

Table 1
Backscatter Calculations referencing Tabata

Isotope	β Energy (MeV)	Branching Ratio	Backscatter Al	Backscatter Fe	Backscatter Cu	Effective Backscatter component Al	Effective Backscatter component Fe (SS)	Effective Backscatter component Cu	Effective Backscatter component Ni approx.
^{214}Pb	0.69	0.47	0.093	0.219	0.243	0.044	0.103	0.114	0.110
	0.74	0.44	0.091	0.215	0.240	0.040	0.095	0.105	0.102
	1.03	0.06	0.079	0.198	0.222	0.005	0.012	0.013	0.013
^{214}Bi	2	0.76	0.052	0.148	0.169	0.040	0.113	0.129	0.123
	3.26	0.19	0.035	0.106	0.122	0.007	0.020	0.023	0.022
^{214}Po	0.01	0.81	0.131	0.254	0.277	0.106	0.206	0.224	0.218
	0.06	0.19	0.128	0.253	0.276	0.024	0.048	0.052	0.051
^{210}Bi	1.16	1	0.074	0.190	0.214	0.074	0.190	0.214	0.206
Average fraction from ^{230}Th radium daughters						0.042	**0.098**	0.109	**0.106**
^{90}Sr	0.372	1	0.110	0.238	0.261	0.110	0.238	0.261	0.254
^{90}Y	1.588	1	0.061	0.167	0.190	0.061	0.167	0.190	0.182
Average fraction from $^{90}Sr^{90}Y$						0.086	**0.203**	0.226	**0.218**

Table 2
Backscatter Correction for EML Foam Disk Absorption

Counting System	Source Number	Counts* with disks 0	Counts* with disks 2	Fractional Transmission Source	Fractional Transmission Isotope ave.	Backscatter from Al Corrected for Foam
LB5100	90(-3.3)-1	1488.4	1100.58	0.739	0.737	**0.063**
	90(-2.1)-3	10646.7	7882.03	0.740		
	90(-2.2)-1	31990.5	23379.3	0.731		
	230(-3.3)-1	699.9	86.55	0.124	0.083	**0.004**
	230(-2.2)-4	4122.1	171.98	0.042		
XLB	90(-3.3)-1	1570.98	1093.82	0.696	0.696	**0.060**
	90(-2.1)-3	11356.3	7955.81	0.701		
	90(-2.2)-1	34219	23631.4	0.691		
	230(-3.3)-1	501.0	87.41	0.174	0.118	**0.005**
	230(-2.2)-4	2833.9	176.5	0.062		

*Count data from references 3 through 15

3.0 $^{90}Sr^{90}Y$ beta counting efficiency

3.1 Analysis using the 90(-3.3)-1 calibration standard source[16] from Eberline:

The 90(-3.3)-1 is an open source, electroplated on a polished nickel (Ni) disk. The source was calibrated by Eberline on 3/19/79 and has a half-life of 28.6 years.

The source calibration (measured) is stated as $^{90}Sr^{90}Y$ with a surface emission rate of 5050 betas/min with an assumed backscatter of 40%. However, referencing Tabata, a value of 21.8% was determined.

The Eberline calibration measurement (2π) of 5050 betas/min with the calculated backscatter of 21.8%, results in a true 4π rate of 8292 dpm, or 138Bq on the calibration date. Correcting for decay results in 76.6 Bq on the measurement date (11/21/03).

The LB5100 count rate from this source is 1512.5 cpm[3] on 11/21/03. Correcting for the backscatter difference (EML sample to calibration source), results in a sensitivity for aluminum backed $^{90}Sr^{90}Y$ β of:

> 1512.5 cpm/76.6 Bq*(1.063/1.218) = 17.23 cpm/Bq;
> where 1.063 is the EML sample correction and 1.218 is the Ni backed source correction.

The XLB count rate from this source is 1571 cpm[4]. Correcting for the backscatter difference (EML sample to calibration source), results in a sensitivity for aluminum backed $^{90}Sr^{90}Y$ β of:

> 1571 cpm/76.6 Bq*(1.060/1.218) = 17.85 cpm/Bq;
> where 1.060 is the EML sample correction and 1.218 is the Ni backed source correction.

3.2 Repeating the above analysis for the 90(-2.1)-3 wipe standard source[17] from IPL:

The 90(-2.1)-3 is a wipe source deposited by wiping a surface with known deposited activity, attaching the wipe to an aluminum planchet and placing a protective 0.9 mg/cm^2 aluminized Mylar cover over the top. The source was calibrated by IPL (using a before-and-after measurement of the active surface) on 4/1/91 and has a half-life of 28.6 years.

The IPL source calibration is stated as 0.01005 mCi of ^{90}Sr. Fermilab measurements revealed a counting rate twice the expected rate for this activity. Examining the calibration sheet for the 90(-2.2)-1 ^{90}Sr source (another IPL source) reveals the calibration stated in 2 ways, first as ^{90}Sr activity only, and second, as $^{90}Sr^{90}Y$ 2π emission rate. Calculating the activity from the 2π rate yields a value twice the stated ^{90}Sr activity. It is obvious that the 90(-2.1)-3 source activity is stated only for ^{90}Sr. Thus, the stated ^{90}Sr activity for this calculation was doubled to 743.7 Bq ($^{90}Sr^{90}Y$). Correcting for decay results in 549.7 Bq on the measurement date (11/20/03).

The LB5100 count rate from this source is 10822 cpm[3] on the same date. The 'open source' counting rate is determined by adjusting the measured counting rate by a factor of 1.03 to compensate for the effects of the aluminized Mylar cover[1]. No adjustment for backscatter was performed as the medium (Al) is the same and the source wipe material is similar to the foam disk. Correcting for the aluminized Mylar cover, the EML sample sensitivity for aluminum backed $^{90}Sr^{90}Y$ β is:

> 10822 cpm/549.7 Bq*(1.03) = 20.28 cpm/Bq

The XLB count rate from this source is 11356 cpm[4] on the same date. Correcting for the aluminized Mylar cover, the EML sample sensitivity for aluminum backed $^{90}Sr^{90}Y$ β is:

11356 cpm/549.7 Bq*(1.03) = <u>21.28 cpm/Bq</u>

3.3 <u>Repeating the above analysis for the 90(-2.2)-1 source[18] from IPL:</u>

The 90(-2.2)-1 is a distributed and evaporated metallic salt on a polymeric membrane with a protective 0.9 mg/cm^2 aluminized Mylar cover. The calibration certificate states the backing is aluminum, however inspection reveals the backing to be stainless steel. The IPL calibration reference date is 11/1/01. It has a half-life of 28.6 years.

The source calibration is stated as 765.5 Bq. (^{90}Sr only), and as a 2π emission rate (on 10/12/01) as 51930 β/min from $^{90}Sr^{90}Y$. Calculating the activity from the 2π measurement yields a value approximately twice the ^{90}Sr activity. As ^{90}Sr is in equilibrium with ^{90}Y, the ^{90}Sr calibration value is doubled to 1531 Bq on 11/1/01. Correcting for decay results in 1455.7 Bq on the measurement date (11/21/03).

The LB5100 count rate from this source is 32504.4 cpm[3] on the same date. Correcting for the backscatter difference (EML sample to calibration source), and aluminized Mylar cover effects, the EML sample sensitivity for aluminum backed $^{90}Sr^{90}Y$ β is:

32504 cpm/1455.7 Bq*(1.063/1.203)*(1.03) = <u>20.32 cpm/Bq</u>

The XLB count rate from this source is 34219 cpm[4] on the same date. Correcting for the backscatter difference (EML sample to calibration source), and aluminized Mylar cover effects, the EML sample sensitivity for aluminum backed $^{90}Sr^{90}Y$ β is:

34219 cpm/1455.7 Bq*(1.060/1.203)*(1.03) = <u>21.33 cpm/Bq</u>

3.4 <u>Average Efficiency of the counting systems for $^{90}Sr^{90}Y$.</u>

Based on the three $^{90}Sr^{90}Y$ beta sources, the average sensitivity of the LB5100 system for $^{90}Sr^{90}Y$ β is:

<u>19.3 cpm/Bq</u>.

And, the average sensitivity of the XLB system for $^{90}Sr^{90}Y$ β, based on these 3 sources, is:

<u>20.2 cpm/Bq</u>.

4.0 ^{230}Th alpha counting efficiency

4.1 Analysis using the 230(-3.3)-1 calibration standard source[19] from Eberline:

The 230(-3.3)-1 source (from Eberline) is an open source, uniformly deposited on a polished nickel disk (the disk material is not stated, but appears to be the same as the ^{90}Sr source from Eberline). The source was calibrated by Eberline on 2/5/73 and has a half-life of 74430 years. The source calibration was stated as 3510 alphas/min at 2π geometry including 1.5% α backscatter; and as 6910 dpm (which cross-checks with the first value) at 4π geometry. Thus the activity is 115 Bq. Due to the long half-life, no correction is made to the calibration value.

The LB5100 count rate from this source is 1736.7 cpm[3]. Eliminating the 1.5% α backscatter component from Ni, the estimated sensitivity of the LB5100 counter for an aluminum backed ^{230}Th α is:

(1736.7 /1.015) cpm/115 Bq = <u>14.9 cpm/Bq</u>

The XLB count rate from this source is 1901.9 cpm[4]. Eliminating the 1.5% α backscatter component from Ni, the estimated sensitivity of the XLB counter for an aluminum backed ^{230}Th α is:

(1901.9 /1.015) cpm/115 Bq = <u>16.3 cpm/Bq</u>

4.2 Repeating this for the 230(-2.2)-4 source[20] from IPL:

The 230(-2.2)-4 source (from IPL) is an open source, electrodeposited and diffusion bonded oxide on a stainless steel disk. The source is covered with approximately 100 μg Au/cm^2. The source was measured by IPL on 10/12/01 with a calibration reference date of 11/1/01.

The source calibration is stated as 755.5 Bq, however with the 100 μg Au/cm^2 cover, the effective activity is reduced. Therefore the measured α rate (IPL) was used to determine the effective activity. 21760 alphas/min at 2π geometry with 1.5% backscatter (estimate) yields an effective activity of 714.6 Bq.

The LB5100 count rate from this source is 11858 cpm[3]. Eliminating the 1.5% α backscatter component from SS, the estimated sensitivity of the LB5100 counter for an aluminum backed ^{230}Th α is:

(11858/1.015) cpm/714.6 Bq = <u>16.3 cpm/Bq</u>

The XLB count rate from this source is 12630 cpm[4]. Eliminating the 1.5% α backscatter component from SS, the estimated sensitivity of the XLB counter for an aluminum backed ^{230}Th α is:

(12630/1.015) cpm/714.6 Bq = <u>17.4 cpm/Bq</u>

4.3 Average Efficiency of the counting systems for $^{90}Sr^{90}Y$.

The average sensitivity of the LB5100 counter for ^{230}Th α, based on these 2 sources, is:

15.6 cpm/Bq.

The average sensitivity of the XLB counter for ^{230}Th α, based on these 2 sources, is:

16.9 cpm/Bq.

5.0 ^{230}Th beta contribution

Calculation of the $^{90}Sr^{90}Y$ contribution to the EML sample total activity can only be performed if the β components of the ^{230}Th and $^{90}Sr^{90}Y$ can be separated

5.1 Referencing the counting data[3] from the LB5100 for the 230(-3.3)-1 source:

$\beta = 699.93$ cpm; $\alpha = 1736.68$ cpm. Adjusting the β counting rate for the backscatter difference (EML sample to calibration source) we have:

$\beta = 699.93 *(1.004/1.106) = 635.4$ cpm for foam disk over Al backing material.

The β/α counting ratio, referenced to the 230(-3.3)-1 source, for the aluminum backed EML samples would be:

$\beta/\alpha = 635.4/1736.7 = \underline{0.366}$

5.2 Referencing the counting data[3] from the LB5100 for the 230(-2.2)-4 source:

$\beta = 4122$ cpm; $\alpha = 11858$ cpm. Adjusting the β counting rate for the backscatter difference (EML sample to calibration source) we have:

$\beta = 4122*(1.004/1.098) = 3769$ cpm for foam disk over Al backing material.

The β/α counting ratio, referenced to the 230(-2.2)-4 source, for the aluminum backed EML samples would be:

$\beta/\alpha = 3769/11858 = \underline{0.318}$

Thus, the average β/α ratio for ^{230}Th from an EML sample counted on the LB5100 system is estimated to be:

0.342.

5.3 Referencing the counting data[4] from the XLB system for the 230(-3.3)-1 source:

β = 501 cpm; α = 1902 cpm. Adjusting the β counting rate for the backscatter difference (EML sample to calibration source) we have:

β = 501*(1.004/1.106) = 454.8 cpm for foam disk over Al backing material.

The β/α counting ratio, referenced to the 230(-3.3)-1 source, for the aluminum backed EML samples would be:

β/α = 454.8/1902 = 0.239

5.4 Referencing the counting data[4] from the XLB system for the 230(-2.2)-4 source:

β = 2833.9 cpm; α = 12630.7 cpm. Adjusting the β counting rate for the backscatter difference (EML sample to calibration source) we have:

β = 2833.9*(1.004/1.098) = 2591.3 cpm for foam disk over Al backing material.

The β/α counting ratio, referenced to the 230(-2.2)-4 source, for the aluminum backed EML samples would be:

β/α = 2591.3/12630.7 = 0.205

Thus, the average β/α ratio for ^{230}Th from an EML sample counted on the XLB system is estimated to be:

0.222.

6.0 Activity Calculation from EML samples

6.1 Calculation from LB5100 System data:

Using the α source sensitivity and the β/α counting ratio for ^{230}Th; and β source sensitivity for ^{90}Sr^{90}Y, the analysis for an EML sample is:

$$^{230}\mathbf{Th\ activity} = \frac{\alpha\ \mathbf{net\ cpm}}{\mathbf{15.6}}\,Bq\ ; \quad \text{and}$$

$$^{90}\mathbf{Sr}\,^{90}\mathbf{Y\ activity} = \frac{\left(\beta\ \mathbf{cpm\ net\ -}\ \alpha\ \mathbf{cpm\ net * 0.34}\right)}{\mathbf{19.3}}\,Bq$$

6.2 Calculation from XLB System data:

Using the α source sensitivity and the β/α counting ratio for ^{230}Th; and β source sensitivity for ^{90}Sr^{90}Y, the analysis for an EML sample is:

$$^{230}\textbf{Th activity} = \frac{\alpha\ \textbf{net cpm}}{\textbf{16.9}}\,Bq\text{ ; and}$$

$$^{90}\textbf{Sr}\,^{90}\textbf{Y activity} = \frac{(\beta\ \textbf{cpm net - }\alpha\ \textbf{cpm net * 0.22})}{\textbf{20.2}}\,Bq$$

If desired, divide the ^{90}Sr^{90}Y activity by 2 to obtain ^{90}Sr activity only.

7.0 Conclusion

The various source backing materials resulted in multiple backscatter corrections and estimated attenuation factors for the EML polyfoam disks. This lends some non-quantified uncertainties to the equations. If the equations provide inconsistent measurement results, the number of sources used in this analysis may have to be reduced. The non-covered, electroplated Eberline sources may be the best choice, as these require the least corrective estimation to be of use in determining the systems responses to the EML samples.

The β and α constants as well as the β/α counting ratios should be periodically checked, using current calibration data, to assure that there are no changes in the sensitivity of either counting system.

References:

1. Radiation Physics Note 96 – Calibration of the Tennelec LB5100 and APC Wipe Counting Systems; Fermilab; 4/92; F. Krueger.

2. An Empirical Equation for the Backscattering Coefficient of Electrons; T. Tabata, et al; Nuclear Instruments and Methods 94 (1971) 509-513.

3. Counting Report from LB5100; check of 5 calibration sources; Fermilab ES&H section, Radiation Protection Group, AAL, Kershisnik; 11/21/03.

4. Count Rate Report (ID#200311201405) from XLB system; check of 5 calibration sources; Fermilab ES&H section, Radiation Protection Group, AAL; 11/20/03.

5. Counting Report from LB5100; check of 3 - ^{90}Sr calibration sources without an EML foam disk attenuator; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/9/03.

6. Counting Report from LB5100; check of 90(-2.2)-1 calibration source with 2 EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/10/03.

7. Counting Report from LB5100; check of 90(-3.3)-1 calibration source with 2 EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/10/03.

8. Counting Report from LB5100; check of 90(-2.1)-3 calibration source with 2 EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/11/03.

9. Counting Report from LB5100; check of 230(-2.2)-4 calibration source with two EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Kershisnik; 11/25/03.

10. Counting Report from LB5100; check of 230(-3.3)-1 calibration source with two EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Kershisnik; 11/25/03.

11. Count Rate Report (ID#200312030827) from XLB system; check of calibration source, 90(-3.3)-1 with 2 EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/3/03.

12. Count Rate Report (ID#200312031012) from XLB system; check of calibration source, 90(-2.2)-1 with 2 EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/3/03.

13. Count Rate Report (ID#200312030634) from XLB system; check of calibration source, 90(-2.1)-3 with 2 EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Benesch; 12/3/03.

14. Count Rate Report (ID#2003111260653) from XLB system; check of calibration source, 230(-3.3)-1 with two EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Kershisnik; 11/26/03.

15. Count Rate Report (ID#2003111260839) from XLB system; check of calibration source, 230(-2.2)-4 with two EML foam disk attenuators; Fermilab ES&H section, Radiation Protection Group, AAL, Kershisnik; 11/26/03.

16. Report of Calibration, Electroplated Beta Source; Serial No. S-1976; Eberline Instrument Corporation; 3/19/79.

17. Certificate of Beta Standard Source; Source No. N-777; Isotope Products Laboratories; 4/1/91.

18. Certificate of Calibration, Beta Standard Source; Source No. A2-565; Isotope Products Laboratories; 10/15/01.

19. Certificate - Thorium 230 Alpha Standard; Serial No. S-598; Eberline Instrument Corporation; 2/5/73.

20. Certificate of Calibration, Alpha Standard Source; Source No. A2-564; Isotope Products Laboratories; 10/15/01.

Appendix 1

Updating EML Sample Analysis Calculations

The LB5100 and XLB systems are periodically checked with a wide variety of sources. The data is then compared to decay corrected values from previous checks. This is particularly important following a gas bottle change with the associated plateau adjustments. The data from the source checks of interest (^{90}Sr and ^{230}Th) can be used to recalculate the calibration for EML samples.

1.0 Source Calibration Reference

The table below contains the calibration reference information for the sources of interest. The decay corrected activity must be determined for each source when recalculating the EML sample efficiencies.

Calibration Source	Calibration Date	Activity (Bq)	Half Life (Years)
90(-3.3)-1	3/19/1979	138	28.52
90(-2.1)-3	4/1/1991	743.7	28.52
90(-2.2)-1	11/1/2001	1531	28.52
230(-3.3)-1	2/5/1973	115	75430
230(-2.2)-4	11/1/2001	714.6	75430

2.0 LB5100 Sensitivity Calculations – using current calibration source count rate data:

2.1 ^{90}Sr^{90}Y - β Source Sensitivity:

For 90(-3.3)-1 source:

$$\frac{\textbf{Net source}\,\beta\,\textbf{cpm}}{\textbf{Decay Corrected Activity (Bq)}} \times \frac{\mathbf{1.063}}{\mathbf{1.218}} = {}^{90}\textbf{Sr}\,{}^{90}\textbf{Y}\,\beta\,\textbf{sensitivity (cpm/Bq)}$$

For 90(-2.1)-3 source:

$$\frac{\textbf{Net source}\,\beta\,\textbf{cpm}}{\textbf{Decay Corrected Activity (Bq)}} \times \mathbf{1.03} = {}^{90}\textbf{Sr}\,{}^{90}\textbf{Y}\,\beta\,\textbf{sensitivity (cpm/Bq)}$$

For 90(-2.2)-1 source:

$$\frac{\textbf{Net source}\beta\textbf{ cpm}}{\textbf{Decay Corrected Activity (Bq)}} \times \frac{1.063}{1.203} \times 1.03 = {}^{90}\text{Sr}^{90}\text{Y } \beta \textbf{ sensitivity (cpm/Bq)}$$

Average ^{90}Sr^{90}Y beta sensitivity for the LB5100 system = _______cpm/Bq.

2.2 ^{230}Th - α and β Source Sensitivity and β/α counting ratios:

For 230(-3.3)-1 source:

$$\frac{\textbf{Net source } \alpha \textbf{ cpm}}{115\,(\text{Bq}) \times 1.015} = {}^{230}\text{Th } \alpha \textbf{ sensitivity (cpm/Bq)}$$

$$\frac{\textbf{Net source } \beta \textbf{ cpm} \times 1.004 \times 1.015}{\textbf{Net source } \alpha \textbf{ cpm} \times 1.106} = {}^{230}\text{Th } \beta/\alpha \textbf{ Count Ratio}$$

For 230(-2.2)-4 source:

$$\frac{\textbf{Net source } \alpha \textbf{ cpm}}{714.6\,(\text{Bq}) \times 1.015} = {}^{230}\text{Th } \alpha \textbf{ sensitivity (cpm/Bq)}$$

$$\frac{\textbf{Net source } \beta \textbf{ cpm} \times 1.004 \times 1.015}{\textbf{Net source } \alpha \textbf{ cpm} \times 1.098} = {}^{230}\text{Th } \beta/\alpha \textbf{ Count Ratio}$$

Average ^{230}Th alpha sensitivity for the LB5100 system = _______cpm/Bq.

Average ^{230}Th β/α count ratio for the LB5100 system = _____.

2.3 EML sample calibration for the LB5100 - using data from the EML sample counted on the LB5100 system.

$${}^{230}\textbf{Th } \alpha \textbf{ Activity} = \frac{\textbf{Net } \alpha \textbf{ cpm}}{\textbf{Average LB5100 system } \alpha \textbf{ sensitivity}} Bq$$

$${}^{90}\textbf{Sr}^{90}\textbf{Y } \beta \textbf{ Activity} = \frac{\textbf{Net } \beta \textbf{ cpm - (Net } \alpha \textbf{ cpm} * \beta/\alpha \textbf{ count ratio)}}{\textbf{Average LB5100 system } {}^{90}\textbf{Sr}^{90}\textbf{Y } \beta \textbf{ sensitivity}} Bq$$

3.0 XLB System Sensitivity Calculations – using current calibration source count rate data:

3.1 <u>$^{90}Sr^{90}Y$ - β Source Sensitivity:</u>

For 90(-3.3)-1 source:

$$\frac{\textbf{Net source}\beta\textbf{ cpm}}{\textbf{Decay Corrected Activity (Bq)}} \times \frac{1.060}{1.218} = {}^{90}\textbf{Sr}^{90}\textbf{Y } \beta \textbf{ sensitivity (cpm/Bq)}$$

For 90(-2.1)-3 source:

$$\frac{\textbf{Net source } \beta \textbf{ cpm}}{\textbf{Decay Corrected Activity (Bq)}} \times 1.03 = {}^{90}\textbf{Sr}^{90}\textbf{Y } \beta \textbf{ sensitivity (cpm/Bq)}$$

For 90(-2.2)-1 source:

$$\frac{\textbf{Net source}\beta\textbf{ cpm}}{\textbf{Decay Corrected Activity (Bq)}} \times \frac{1.060}{1.203} \times 1.03 = {}^{90}\textbf{Sr}^{90}\textbf{Y } \beta \textbf{ sensitivity (cpm/Bq)}$$

Average $^{90}Sr^{90}Y$ beta sensitivity for the XLB system = ______cpm/Bq

3.2 <u>^{230}Th - α and β Source Sensitivity and β/α counting ratios:</u>

For 230(-3.3)-1 source:

$$\frac{\textbf{Net source } \alpha \textbf{ cpm}}{\textbf{115 (Bq)} \times 1.015} = {}^{230}\textbf{Th } \alpha \textbf{ sensitivity (cpm/Bq)}$$

$$\frac{\textbf{Net source } \beta \textbf{ cpm} \times 1.004 \times 1.015}{\textbf{Net source } \alpha \textbf{ cpm} \times 1.106} = {}^{230}\textbf{Th } \beta/\alpha \textbf{ Count Ratio}$$

For 230(-2.2)-4 source:

$$\frac{\textbf{Net source } \alpha \textbf{ cpm}}{\textbf{714.6 (Bq)} \times 1.015} = {}^{230}\textbf{Th } \alpha \textbf{ sensitivity (cpm/Bq)}$$

$$\frac{\textbf{Net source } \beta \textbf{ cpm} \times 1.004 \times 1.015}{\textbf{Net source } \alpha \textbf{ cpm} \times 1.098} = {}^{230}\textbf{Th } \beta/\alpha \textbf{ Count Ratio}$$

Average ^{230}Th alpha sensitivity for the XLB system = ______cpm/Bq.

Average ^{230}Th β/α count ratio for the XLB system = ________.

3.3 EML sample calibration for the XLB system - using data from the EML sample counted on the XLB system.

$$^{230}\textbf{Th}\ \alpha\ \textbf{Activity} = \frac{\textbf{Net}\ \alpha\ \textbf{cpm}}{\textbf{Average XLB system}\ \alpha\ \textbf{sensitivity}}\ Bq$$

$$^{90}\textbf{Sr}\,^{90}\textbf{Y}\ \beta\ \textbf{Activity} = \frac{\textbf{Net}\ \beta\ \textbf{cpm - }\left(\textbf{Net}\ \alpha\ \textbf{cpm} * \beta/\alpha\ \textbf{count ratio}\right)}{\textbf{Average XLB system}\ ^{90}\textbf{Sr}\,^{90}\textbf{Y}\ \beta\ \textbf{sensitivity}}\ Bq$$